Comparing Structure Learning Algorithms Across Different Libraries

Tian Cheng Xia

06/02/2024

FAIKR Module 3

Alma Mater Studiorum · University of Bologna

Aim

1. Explore the available open-source Python libraries for Bayesian network structure learning.
2. Compare the various structure learning algorithms implemented in them.

Libraries and algorithms

Structure learning algorithms	**Library**		
	`pgmpy` `bnlearn`	`pomegranate`	`pyAgrum`
Score-based	Hill-climbing Exhaustive search	A*	Hill-climbing Tabu search K2
Tree-based	Chow-Liu Naive Bayes Tree-augmented NB	Chow-Liu	Chow-Liu Naive Bayes Tree-augmented NB
Constraint-based	PC	—	MIIC
Hybrid	Max-min hill-climbing	—	—

Table: Tested libraries and available structure learning algorithms.

Evaluation approach

- Evaluate on classification tasks.
- MLE as parameter learning algorithm.
- Variable elimination to solve queries.

Datasets

Apple quality

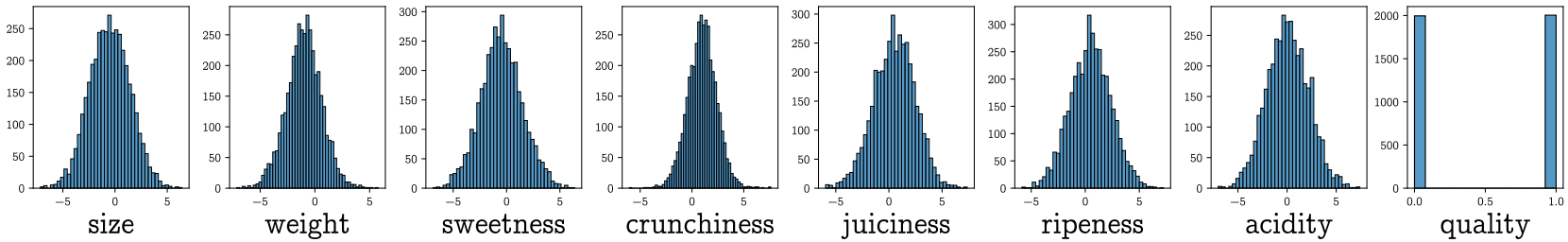


Figure: Apple quality data distribution

Heart disease

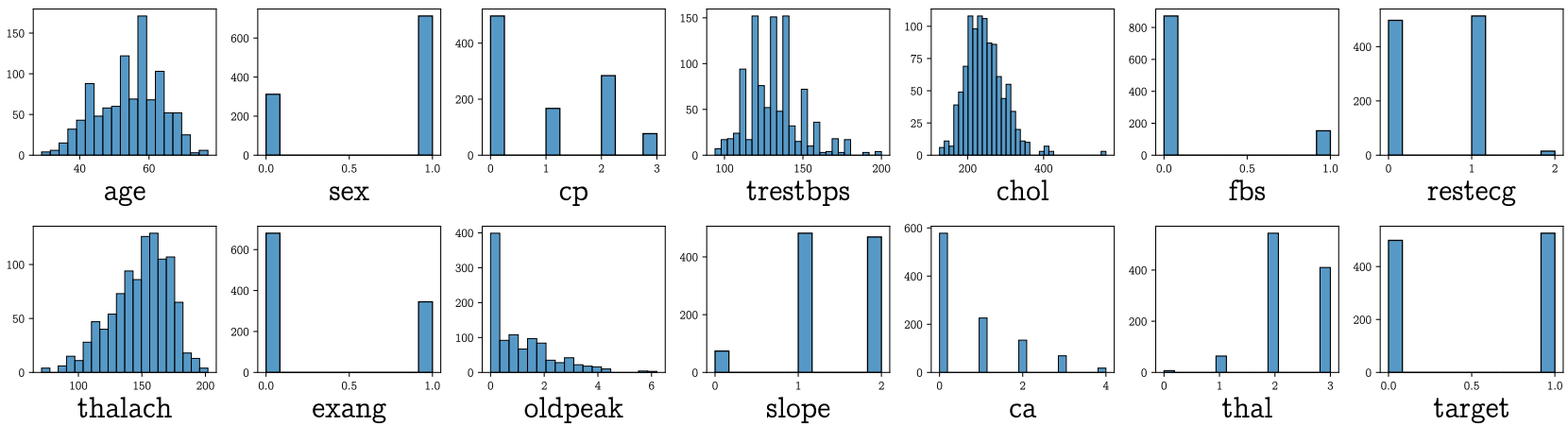
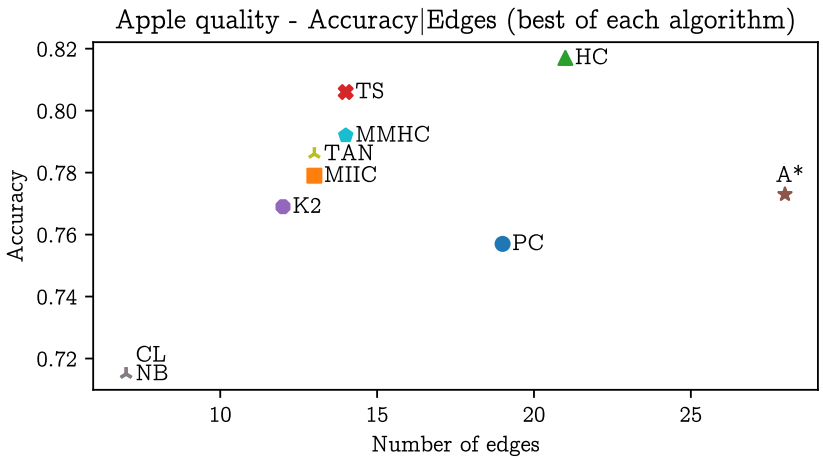
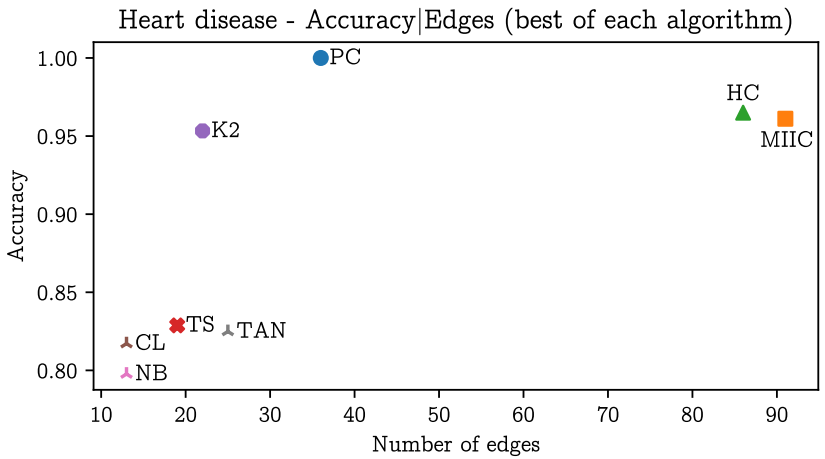


Figure: Heart disease data distribution

Results

Accuracy vs number of edges

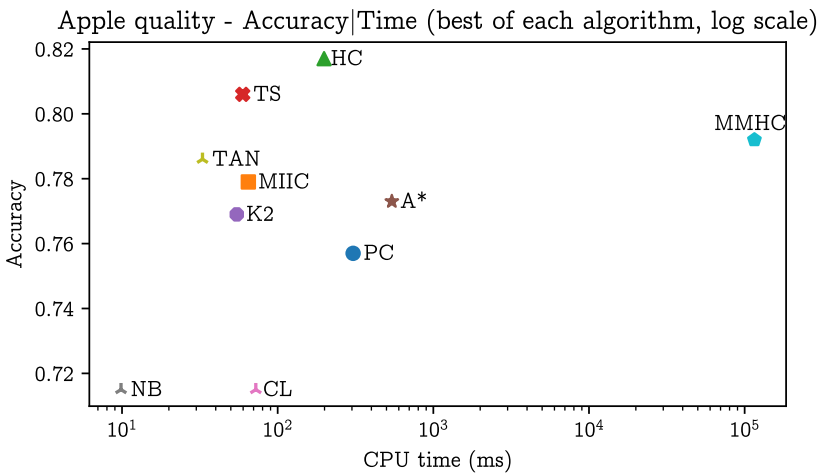


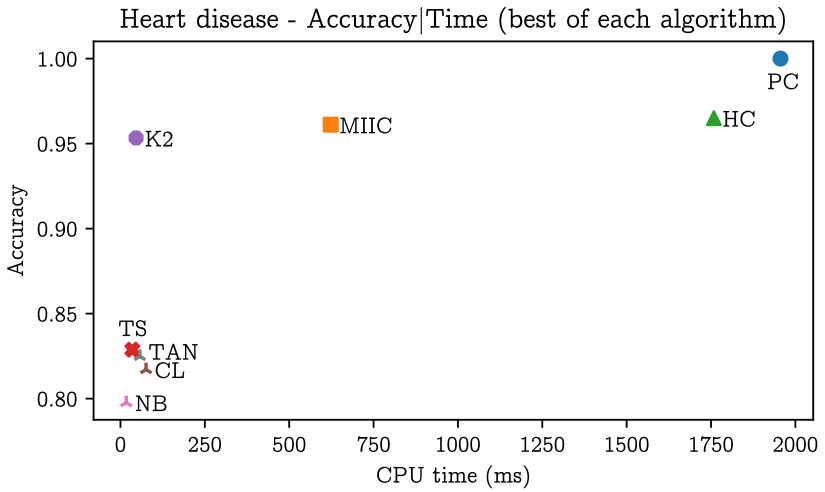


- Score-based methods work better on the apple quality dataset.
- Constraint-based methods work better on the heart disease dataset.
- Tree-based methods generally perform worse than the others but learn smaller topologies.
- The choice of the independence test/fitness score heavily influences the final result.

Results

Accuracy vs CPU time





- Tree-based methods are generally the fastest.
- PC, hill-climbing, A*, and MMHC are among the slowest.
- Execution time and number of learned edges are not strictly related.

Results

Visual comparison

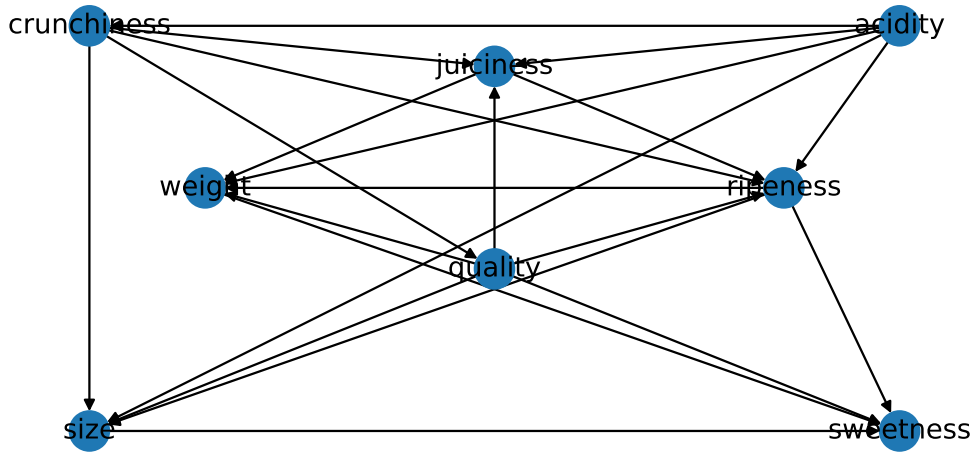


Figure: Apple quality – Hill-climbing (K2 score) result

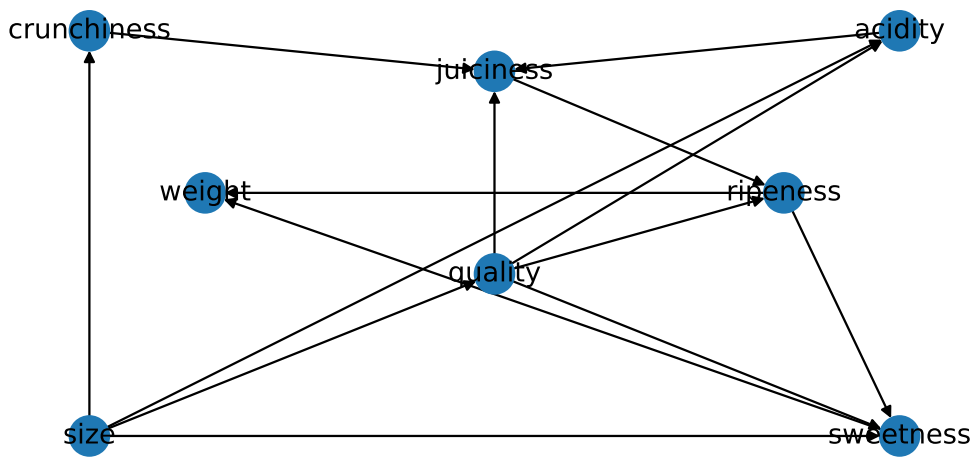


Figure: Apple quality – Tabu search result

Observations

- Score-based and constraint-based methods generally perform better than tree-based methods.
- Tree-based methods generally produce simpler topologies.
- The choice of the best structure learning algorithm depends on the data.

Limits

- This mini-project only focuses on a classification-oriented evaluation.
- Only a small number of datasets have been experimented.
- The evaluation of the execution time is very informal and the different backends of each library must be taken into account.